Notice No.4

Rules and Regulations for the Classification of Ships, July 2021

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

Please note that corrigenda amends to paragraphs, Tables and Figures are not shown in their entirety.

Issue date: November 2021

Amendments to	Effective date	IACS/IMO implementation (if applicable)
Part 5, Chapter 12, Section 9	1 January 2022	1 January 2022
Part 5, Chapter 14, Section 4	1 January 2022	N/A
Part 5, Chapter 24, Sections 5, 7, 9, 10 & 11	1 January 2022	1 January 2022
Part 5, Chapter 26 (New)	1 January 2022	N/A
Part 6, Chapter 2, Sections 1 & 7	1 January 2022	N/A
Part 7, Chapter 13, Sections 3, 4, 5 & 6	1 January 2022	N/A
Part 8, Chapter 2, Sections 4 & 10	1 January 2022	N/A

Lloyd's Register

Part 5, Chapter 12
Piping Design Requirements

■ *Section 9*
Piping for LPG/LNG carriers, gas fuelled ships and classed refrigeration systems

9.8 Expansion bellows

9.8.1 The following plans and particulars are to be submitted:

(a) Dimensioned drawings of each type of bellows.

(b) Design calculations to show that the bellows are suitable for the intended design conditions, carried out to EJMA (Expansion Joint Manufacturers Association) standards (latest edition) or equivalent.

(c) A proposed type test program covering the tests detailed in *Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems* of the ~~Rules for Ships for Liquefied Gases~~ *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

(d) Calculations to EJMA standards may be accepted, together with sample testing detailed above, in order to cover the entire size range for the type.

(e) Thermal insulation protection, if applicable.

9.8.6 A cyclic fatigue test, representing ship deformation, is to be performed on a complete expansion joint (inclusive of its thermal insulation when fitted, where the thermal insulation is an integral part of the joint; however, this test could be performed without insulation where the thermal insulation is completely independent of the bellows movement), without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. NDE is required after cyclic testing. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

Part 5, Chapter 14
Machinery Piping Systems

■ *Section 4*
Fuel oil pumps, pipes, fittings, tanks, etc.

4.11 Filling arrangements

4.11.2 Provision is to be made against ~~over-pressure~~ overpressure in the filling pipelines~~, and~~. Where any relief valve(s) are fitted for this purpose ~~is~~, they are to discharge to an overflow tank or other safe position.

Part 5, Chapter 24
Emissions Abatement Plant for Combustion Machinery

■ *Section 5*
Hull construction

5.1 General

5.1.5 Where independent tanks are used for chemical substances, these are to be arranged as far as practicable so as to contain spillage.
~~This may be achieved by using a double skinned storage tank, by means of a spill containment bund or by placing the tank in a dedicated compartment. Where a bund is to be used, it is to comply with the following:~~

~~(a) the bund is dimensioned so as to contain the maximum contents of the tank at the angles of inclination required for main and auxiliary machinery in *Table 1.3.2 Inclination of ship* in *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery*; or~~

~~(b) (b)there is a drain arrangement meeting the requirements of *Pt 5, Ch 24, 5.1 General 5.1.7*. If the tank is located in a dedicated compartment then the compartment is to contain no equipment other than that required by the tank with permanent access and floor plates positioned above the liquid level if the tank were to discharge its full contents into the compartment. Any valves, equipment and emergency stop functions are to be operable from outside this compartment and are to meet the requirements of *Pt 5, Ch 24, 5.2 Location service and control spaces*.~~

Tanks and spill containment arrangements are to be fitted with alarms and safeguards, in accordance with *Pt 5, Ch 24, 9.1 General 9.1.11*.

5.1.8 Chemical storage tanks containing substances which are ~~categorised as a safety hazard in *Chapter 17* of the Rules for Ships for Liquid Chemicals (designated by letter "S" in column d)~~ used for emissions abatement plant are subject to special consideration where they are located in the same space as essential services, e.g. main combustion machinery and equipment. ~~These tanks are to form part of the ship's structure and the area of the tank boundary common with the machinery spaces is to be kept to a minimum as required for fuel oil tanks, as far as practicable.~~ Tanks for chemical substances are not to be situated where spillage or leakage therefrom can constitute a hazard by dripping or spraying onto combustibles or hot surfaces.

■ *Section 7* Pumping and piping

7.1 General

7.1.1 Pipe work and transfer systems which may carry chemical substances are to meet the requirements of *Pt 5, Ch 12 Piping Design Requirements, Pt 5, Ch 13 Ship Piping Systems* and *Pt 5, Ch 14 Machinery Piping Systems*, as applicable. ~~Pipe joints for chemical substances which are categorised as a safety hazard in *Chapter 17* of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (designated by letter "S" in column d) are to be butt-welded, except in way of valves or equipment, and Class I piping systems are to be used regardless of design pressure in storage, handling and supply systems.~~ Where it is proposed to apply corrosion resistant lining to steel pipe systems then such lining is to be confirmed as being suitable for the application, in accordance with *Pt 5, Ch 24, 4.1 General 4.1.2*. The elasticity of the lining is not to be less than that of the supporting boundary material.

7.1.3 Chemical transfer and control arrangements are to be provided with a stop-valve, capable of being manually operated on each tank filling and discharge line, which ~~where~~ as practicable is to be attached directly to the tank plating. Additionally, a stop valve is to be provided at each chemical-hose loading connection. ~~Where there is a possibility of gravity discharge of the tank contents in the event of a pipe or valve failure then the stop valve is to be of the quick shut-off type and where the chemical is categorised as a safety hazard in *Chapter 17* of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk* (designated by letter "S" in column d), the stop valve is to be remotely operated and be capable of local manual closure. The closure of the valve shall not impact the operation of essential services.~~

7.2 Ammonia solution piping

7.2.1 Pipes/piping systems containing ammonia solution (*see Pt 5, Ch 24, 10.3 Ammonia solution*) are to be of steel or other equivalent material with a melting point above 925°C, except downstream of a tank valve, provided that this valve is metal seated and, in the event of fire, is arranged either as fail-to-closed or equipped with quick closing facilities operable from a safe position outside the space. In such cases, Type Approved plastic piping is acceptable without the need for fire endurance testing.

7.3 Sodium hydroxide solution (NaOH) or calcium hydroxide solution ($Ca(OH)_2$) piping

7.3.1 All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. In cases where such valves are provided below top of tank, they are to be arranged with quick acting shutoff valves, which are to be capable of being remotely operated from a position safely accessible in the event of chemical treatment fluid leakage.

7.3.2 Pipe joints for sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) solutions (*see Pt 5, Ch 24, 10.4 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution ($Ca(OH)_2$)*) are to be fully welded, except in way of valves or equipment, and are to be considered Class I piping systems regardless of design pressure in storage, handling and supply systems.

7.3.3 The following connections containing sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) solutions (*see Pt 5, Ch 24, 10.4 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution ($Ca(OH)_2$)*) are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:
(a) detachable connections between pipes (flanged connections and mechanical joints, etc.);
(b) detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and
(c) detachable connections between equipment mentioned in *Pt 5, Ch 24, 7.3 Sodium hydroxide solution (NaOH) or calcium hydroxide solution ($Ca(OH)_2$) piping 7.3.3(b)*.

■ *Section 9* Electrical and control equipment

9.1 General

(Part only shown)

Table 24.9.1 Machinery emissions to air abatement plant: alarms and safeguards

Note 3. The process tank is any tank forming part of a wet abatement system flow loop or effluent tanks which receive bleed-off from the main flow loop, or such tanks not forming part of the system flow loop but which are essential for operation of the system, including drain tanks, residue tanks, leakage tanks and those on exhaust gas recirculating installations, *see Pt 5, Ch 24, 11.1 General 11.1.8*. Where low level can present a hazard, process tanks are also to have low level protection.

■ *Section 10*
Storage and use of chemicals

10.1 ~~Sodium hydroxide solution~~ General

10.1.1 Chemical storage tanks ~~that contain sodium hydroxide (NaOH) solution (e.g. 50 per cent aqueous solution) are to comply with the requirements given in~~ ~~*Pt 5, Ch 24, 10.1 Sodium hydroxide solution 10.1.2*~~ ~~to~~ ~~*Pt 5, Ch 24, 10.1 Sodium hydroxide solution 10.1.19*~~ are to meet the requirements of *Pt 5, Ch 24, 10.1 General* and *Pt 5, Ch 24, 10.2 Sodium bicarbonate*, *Pt 5, Ch 24, 10.3 Ammonia solution* or *Pt 5, Ch 24, 10.4 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution (Ca(OH)₂)* as applicable.

10.1.5 Where chemical storage tanks are integrated, the following are to be considered during the design and construction:
- These tanks shall be designed and constructed as integral part of the hull (e.g. double bottom, wing tanks);
- These tanks shall be coated with appropriate anti-corrosion coating or shall be made of adequate corrosion resistant materials ~~and cannot be located adjacent to any fuel oil and fresh water tank~~;
- These tanks shall be designed and constructed in accordance with the structural requirements applicable to hull and primary support members described in *Pt 5, Ch 24, 5 Hull construction*; and
- These tanks shall be included in the ship's stability calculation.

10.1.6 The chemical storage tank piping is to meet the requirements of *Pt 5, Ch 24, 7.1 General 7.1.1* and *Pt 5, Ch 24, 7.2 Ammonia solution piping* or *Pt 5, Ch 24, 7.3 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution (Ca(OH)₂) piping* as applicable.

10.1.7 Pipes or other tank penetrations are to be provided with manual shut-off valves attached to the tank in accordance with *Pt 5, Ch 24, 7.1 General 7.1.3* and *Pt 5, Ch 24, 7.2 Ammonia solution piping 7.2.1* or *Pt 5, Ch 24, 7.3 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution (Ca(OH)₂) piping 7.3.1* as applicable.

10.1.10 ~~Piping systems, tanks and other components which will come into contact with the chemical~~ Chemical storage tanks are to be of ~~a non-combustible material~~ steel or other equivalent material with a melting point above 925°C and are to be made with a material compatible with chemical treatment fluids or coated with appropriate anti-corrosion coating ~~suitable for the intended chemical and application~~.

10.1.15 Where a chemical storage tank is located within an engine room, a separate ventilation system defined in *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.~~8~~11* is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank, and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

10.1.18 For the protection of personnel, the ship is to have suitable personnel protective equipment on board, including protective clothing, safety boots, gloves, tight-fitting goggles. ~~such as, but not limited to, aprons, gloves, boots and safety goggles. Eyewash stations are to be provided in locations where chemical contact is most likely to occur. The location (e.g. near chemical storage tank, loading area, etc.) and number of these eyewash stations is to be derived from the detailed installation arrangements.~~ The amount of personal protective equipment carried on board is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of failure. In no case is there to be less than two sets available on board.

10.1.19 The requirements for the ventilation system specified in the paragraphs *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.11* and *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.12* also apply to the following closed compartments normally entered by persons:
- When such closed compartments are adjacent to the integral ~~urea~~ chemical storage tanks and there are possible leakage points (e.g. manholes, fittings) from these tanks~~;~~.
- When the chemical piping systems pass through such compartments, unless the piping system is made of steel or other equivalent material with a melting point above 925°C and with fully welded joints.

10.2 Sodium bicarbonate

10.2.2 Suitable personnel protection shall be provided in accordance with *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.~~19~~18*.

10.3 Ammonia solution

10.3.1 Chemical storage tanks that contain urea-based ammonia (e.g. 40 per cent urea with 60 per cent water solution), hereinafter referred to as urea solution, as a reductant, are to comply with the requirements given in *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.2* to *Pt 5, Ch 24, 10.1 ~~Sodium hydroxide solution~~ General 10.1.19*~~,~~. ~~and~~
- ~~Tanks are to be of steel or other equivalent material with a melting point above 925°C.~~
- ~~Pipes/piping systems are to be of steel or other equivalent material with melting point above 925°C, except downstream of the tank valve, provided this valve is metal seated and, in the event of fire, is arranged as fail-to-closed or equipped with quick closing facilities operable from a safe position outside the space. In such cases, Type Approved plastic piping is acceptable without the need for fire endurance testing.~~
- ~~Tanks and pipes/piping systems are to be made with materials compatible with reductant or coated with appropriate anti-corrosion coating.~~

10.3.2 ~~In addition to *Pt 5, Ch 24, 10.1 Sodium hydroxide solution 10.1.3*, the~~ The physical storage conditions recommended by applicable and ~~recognized~~ recognised standards (such as ISO18611-3 *Ships and marine technology – Marine NOx reduction agent Aus 40 – Part 3: Handling, transportation and storage*) are to be taken into account to avoid any impairment of urea solution during storage.

10.3.4 Where chemical storage tanks are integrated, these are to comply with *Pt 5, Ch 24, 10.1 General 10.1.5* and cannot be located adjacent to any fuel oil and fresh water tank.

10.3.5 The ship is to provide eyewash stations. The location and number of these eyewash stations is to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

(a) in the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck;

(b) in the vicinity of a chemical bunkering station on-deck; if the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash stations, one for each side; and

(c) in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

10.4 Sodium hydroxide solution (NaOH) or calcium hydroxide solution ($Ca(OH)_2$)

10.4.1 The aqueous solution of sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) is commonly used as a chemical treatment fluid for exhaust gas cleaning system (EGCS), hereinafter referred to as chemical treatment fluid. Chemical storage tanks that contain chemical treatment fluid are to comply with the requirements given in *Pt 5, Ch 24, 10.1 General 10.1.2* to *Pt 5, Ch 24, 10.1 General 10.1.19*. For emissions abatement plant using chemicals other than the above, safety measures are to be taken according to the result of a risk assessment conducted to analyse the risks, in order to eliminate or mitigate the hazards to personnel brought by the use of such systems.

10.4.2 Chemical storage tanks containing chemical treatment fluids (*see Pt 5, Ch 24, 10.4 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution ($Ca(OH)_2$)*) are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2,4 m above the top plate, taking into consideration the density of the chemical treatment fluid.

10.4.3 Where chemical treatment fluid is stored in integral tanks, these are to comply with *Pt 5, Ch 24, 10.1 General 10.1.5* and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner, as well as any food stores, oil tanks or fresh water tanks.

10.4.4 The ship is to provide eyewash and safety shower stations. The location and number of these eyewash and safety shower stations are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

(a) in the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck;

(b) in the vicinity of a chemical bunkering station on-deck; if the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash and safety shower stations, one for each side; and

(c) in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

■ *Section 11*
SOx emissions abatement plant

11.1 General

11.1.12 The chemical storage tank requirements ~~for NaOH solution~~ stated in *Pt 5, Ch 24, 10.~~1~~4 Sodium hydroxide solution (NaOH) or Calcium hydroxide solution ($Ca(OH)_2$)* are applicable for closed loop wet scrubbers and hybrid scrubbers whereas for sodium bicarbonate ~~power~~ powder used in dry scrubbers the requirements stated in *Pt 5, Ch 24, 10.2 Sodium bicarbonate* are applicable.

11.1.14 The holding tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

(a) The tanks are to be independent from other tanks, except in cases where these tanks are also used as the overflow tanks for chemical treatment fluids storage tank.

(b) Tank capacities are to be decided in consideration of the number and kinds of installed exhaust gas cleaning systems as well as the maximum number of days between ports where residue can be discharged ashore. In the absence of precise data, a figure of 30 days is to be used.

(c) Where residue tanks used in closed loop chemical treatment systems are also used as the overflow tanks for chemical treatment fluid storage tanks, the requirements for storage tanks apply.

Part 5, Chapter 26
Fuel Cell Power Installations

■ *Section 1* General

1.1 Goal

1.1.1 The goal of these Rules is to provide safe and reliable delivery of electrical and/or thermal energy through the use of fuel cell technology.

1.1.2 These Rules do not substitute or supersede statutory conventions but do include fire safety requirements additional to those stated in the statutory conventions specific to the use of fuel cell power systems.

1.1.3 Additional requirements may be imposed by the Administration with which the ship is registered and/or by the Flag Administration within whose territorial jurisdiction the ship is intended to operate.

1.1.4 These Rules specify requirements for fuel cell power installations on board ships that comply with either the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels* or the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

1.1.5 All references to the IMO IGF Code throughout these Rules are to be interpreted as references to the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*, which are fully consistent with the IGF Code.

1.2 Functional requirements

1.2.1 The safety, reliability and dependability of the systems shall be equivalent to those achieved with new and comparable conventional oil-fuelled main and auxiliary machinery installations, regardless of the specific fuel cell type and fuel.

1.2.2 The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions should be initiated.

1.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the fuel cell power installation do not lead to an unacceptable loss of power.

1.2.4 Hazardous areas shall be restricted, as far as practicable, to minimise the potential risks that might affect the safety of the ship, persons on board and equipment.

1.2.5 Equipment installed in hazardous areas shall be minimised to that required for operational purposes and should be suitably and appropriately certified.

1.2.6 Fuel cell spaces shall be configured to prevent any unintended accumulation of explosive, flammable or toxic gas concentrations.

1.2.7 System components shall be protected against external damages.

1.2.8 Sources of ignition in hazardous areas shall be minimised to reduce the probability of explosions.

1.2.9 Piping systems and overpressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.

1.2.10 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

1.2.11 Fuel cell spaces shall be arranged and located such that a fire or explosion in one will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

1.2.12 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.

1.2.13 Fixed leakage detection suitable for all spaces and areas concerned shall be arranged.

1.2.14 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.

1.2.15 Commissioning, trials and maintenance of fuel systems and gas utilisation machinery shall satisfy the goal in terms of safety, availability and reliability.

1.2.16 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable Rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

1.2.17 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

1.2.18 Safe access shall be provided for operation, inspection and maintenance.

1.3 Definitions

1.3.1 For the purpose of these Rules, the terms used have the meanings defined in the following paragraphs. Terms not defined have the same meaning as in SOLAS Chapter II-2 and the IGF Code.

1.3.2 Differential cell pressure is the difference in pressure across the electrolyte as measured from one electrode to the other.

1.3.3 Exhaust air is exhaust from the cathode side of the fuel cell.

1.3.4 Exhaust gas is exhaust from the reformer or anode side of the fuel cell.

1.3.5 Fuel is fuel used by the fuel cell either directly or following onboard reforming.

1.3.6 Fuel cell is a source of electrical power in which the chemical energy of a fuel cell fuel is converted directly into electrical and thermal energy by electrochemical oxidation. IEC 62282-2-100 *Fuel cell technologies - Part 2-100: Fuel cell modules – Safety*, defines fuel cell to be an electrochemical device that converts the chemical energy of a fuel and an oxidant to electrical energy (DC power), heat and reaction products.

1.3.7 Fuel cell stack means the assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen-rich gas and air-reactants to DC power, heat and other reaction products. IEC 62282-2-100 *Fuel cell technologies - Part 2-100: Fuel cell modules - Safety*, defines fuel cell stack to be an assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen rich gas and air reactants to DC power, heat and other reaction products.

1.3.8 Fuel cell module is an assembly of one or more fuel cell stacks, their electrical connections and associated equipment and devices which are enclosed within a single casing. IEC 60050-485 *International Electrotechnical Vocabulary (IEV) - Part 485: Fuel cell technologies*, defines fuel cell module to be an assembly incorporating one or more fuel cell stacks and other main and, if applicable, additional components, which is intended to be integrated into a power system.

1.3.9 Fuel cell power system is the group of components which may contain fuel or hazardous vapours, fuel cell(s), fuel reformers, if fitted, and associated piping systems. IEC60050-485 *International Electrotechnical Vocabulary (IEV) - Part 485: Fuel cell technologies*, defines fuel cell power system to be a generator system that uses one or more fuel cell module(s) to generate electric power and heat.

1.3.10 Fuel cell space is a space or enclosure containing fuel cell power systems or parts of fuel cell power systems.

1.3.11 Fuel cell power installation is the fuel cell power system and other components and systems required to supply electrical power to the ship. It may also include auxiliary systems for the fuel cell operation.

1.3.12 Fuel reformer is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed fuel for use in the fuel cells. The fuel reformer forms part of the fuel cell power system.

1.3.13 LEL means lower explosive limit, which, in the context of these Interim Guidelines, should be taken as identical to the Lower Flammable Limit (LFL) and which is 4,0 per cent volume fraction for hydrogen, note: for flammability limits for hydrogen refer to *ISO /TR 15916 Basic considerations for the safety of hydrogen systems*.

1.3.14 Oxidant is air, oxygen gas or oxygen rich compounds used to oxidise fuel within the fuel cell stack.

1.3.15 Power conditioning system regulates and conditions the electrical output of the fuel cell modules to meet the requirements of the onboard electrical distribution system or electrical consumers supplied by the fuel cell power system. The power conditioning system is an auxiliary system which forms part of the fuel cell power installation.

1.3.16 Primary fuel is fuel supplied to the fuel cell power system.

1.3.17 Process air is air supplied to the reformer and/or the cathode side of the fuel cell.

1.3.18 Reformed fuel is hydrogen or hydrogen-rich gas generated in the fuel reformer.

1.3.19 Service profile for the purposes of these Rules is the operational envelope of the fuel cell power system indicating all the intended operational points including any short-term high-power operation.

1.3.20 Thermal management system provides cooling and/or heating to the fuel cell power system, humidity management and condensate removal. The thermal management system is an auxiliary system which forms part of the fuel cell power installation.

1.3.21 Ventilation air is air used to ventilate the fuel cell space.

1.3.22 Ventilation system provides air to spaces or to enclosures. The ventilation system is an auxiliary system which forms part of the fuel cell power installation.

■ *Section 2*
Risk based studies

2.1 Risk assessment

2.1.1 A risk assessment specific to fuel cell power installations is to be carried out for each installation on board. The risk assessment is to evaluate risks related to the safe operation of the ship and as such is to address the safety of the fuel cell power installation itself and, where the fuel cell installation provides power for propulsion of the ship or other essential services, the dependability of the fuel cell power installation.

2.1.2 The risk assessment may be additional to or included in the risk assessment required elsewhere by the Rules, including as required by *Pt A, 4.2 Risk assessment* of the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels* and *Ch 16, 16.9 Alternative fuels and technologies LR 16.9-02* of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

2.1.3 For any new or altered concept or configuration of a fuel cell power installation a risk analysis shall be conducted in order to ensure that any risks arising from the use of fuel cells affecting the safety, reliability and dependability of the ship are addressed.

Consideration shall be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure.

2.1.4 The risks shall be analysed using acceptable and recognised risk assessment techniques, and mechanical damage to components, operational and weather-related influences, electrical faults, unwanted chemical reactions, toxicity, auto-ignition of fuels, fire, explosion, and short-term power failure (blackout) shall as a minimum be considered. The assessment shall ensure that risks are eliminated wherever possible. Risks which cannot be eliminated shall be mitigated as necessary.

2.1.5 System safe states are to be considered with regard to the behaviour and characteristics of the fuel and fuel cell power installation.

2.1.6 Where fuel cell modules are intended to be supplied with oxidant in the form of oxygen gas or oxygen enriched compounds, this is to be specifically addressed in the engineering and safety justification. Such proposals are subject to special consideration.

2.1.7 Where any part of the fuel cell power installation is intended to operate with a continuous leakage of flammable gas, this is to be specifically addressed in the engineering and safety justification. Such proposals are subject to special consideration. The leakage rate is to be calculated in accordance with a recognised International or National Standard such as IEC 62282-3-100 – *Fuel Cell Technologies Part 3-100: Stationary fuel cell systems – Safety*.

2.1.8 Where fuel cell modules incorporate catalytic oxidation or controlled combustion units in order to prevent the accumulation of flammable gases or vapours, this is to be specifically addressed in the engineering and safety justification. Such proposals are subject to special consideration.

2.2 Alternative design

2.2.1 These Rules contain functional requirements for all appliances and arrangements related to the usage of fuel cell technology.

2.2.2 Appliances and arrangements of fuel cell power systems may deviate from those set out in these Rules, provided that such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant sections.

2.2.3 The equivalence of the alternative design shall be demonstrated as specified in SOLAS Chapter II-1, Regulation 55 and approved by the Administration. However, the Administration should not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus or item of equipment or type thereof which is prescribed by these Rules.

2.3 System dependability assessment

2.3.1 Where fuel cell power installations are used to supply power for propulsion of the ship or other essential services then a system dependability assessment is to be undertaken. The assessment is to demonstrate that the dependability of power from the fuel cell power installation is commensurate with that provided by conventional oil-fuelled reciprocating or rotating machinery. The assessment is to include consideration of reliability, availability and maintainability of the fuel cell power installation, taking account of any potential single-point failures and common mode failures and of the need for redundancy of components and equipment.

2.3.2 The system dependability assessment is to be undertaken to a recognised International or National Standard such as IEC 60300-3-1 *Dependability management Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology*.

■ *Section 3*
Documentation for review

3.1 Ship profile, principle of operation and risk analysis

3.1.1 The documentation described below is to be submitted for information:

(a) Details of the intended service profile of the fuel cell power installation together with a description of the intended services that are to be supplied by the fuel cell power installation.

(b) A Design Statement detailing the safety concept, operating principles and philosophy of the fuel cell power installation and all associated sub-systems such as fuel reforming, oxidant supply, thermal management and power conditioning, and the power conditioning requirements such as the rated output voltage, current and frequency.

(c) Schedule of testing at the manufacturer’s works to demonstrate that the fuel cell power installation is capable of operating as described in the service profile Design Statement, including any testing required to confirm the conclusions of the engineering and safety justification. The test schedules are to consider all modes of operation.

(d) Schedule of onboard commissioning tests and sea trials which are intended to ensure that the fuel cell power installation operates in accordance with the service profile and Design Statement when installed on board.

(e) Operating and maintenance manuals detailing the installation, operating and maintenance instructions.

3.1.2 The documentation described below is to be submitted for appraisal:

(a) Engineering and safety justification documentation demonstrating that the safety of the fuel cell power installation is commensurate with conventional oil-fuelled reciprocating and rotating machinery.

(b) Where fuel cell power installations are used to supply power for propulsion of the ship or other essential services, system dependability assessment documentation demonstrating that the dependability of the fuel cell power installation shall be of an equivalent level of dependability to that achieved with new and comparable conventional oil-fuelled reciprocating and rotating main and auxiliary machinery.

(c) A fire safety engineering analysis where required by Statutory Requirements.

3.2 Installation arrangements

3.2.1 The documentation described below is to be submitted for information:

(a) General arrangement plans showing fuel cell spaces relative to fuel bunkering stations, fuel storage tanks, fuel processing equipment, high fire risk areas, accommodation, service and control spaces, water ballast and tanks containing flammable substances.

(b) Drawings and details of equipment enclosures including design pressures and any blast relief arrangements.

(c) Details of any parts of the fuel cell power system which in normal and reasonably foreseeable abnormal conditions may exceed 220°C and of cooling or lagging arrangements.

(d) Details of the purity and composition of inert gas for purging and relevant International or National Standards for quality.

3.2.2 The documentation described below is to be submitted for appraisal:

(a) Plans of hazardous areas and a schedule of electrical equipment for use in explosive gas atmospheres associated with the fuel cell power installation, indicating the locations of hazardous areas.

(b) Plans of the ventilation system for the fuel cell power installation including fuel cell spaces, enclosures, casings including airlocks, ventilation hoods, pipe ducting and any dampers, closing appliances and the position of the controls.

3.3 Fuel and oxidant

3.3.1 The documentation described below is to be submitted for information:

(a) Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P&IDs) for the fuel and oxidant supplies.

(b) Description of the fuel and oxidant supply arrangements and a list of monitoring, control and alarm points.

(c) Details of the composition of fuel, including primary fuel proposed for reforming on board and the reformed fuel, including details of the toxicity, flammability, corrosivity and reactivity of the fuels.

(d) Details of purity and composition requirements for fuels and relevant International or National Standards for quality.

(e) Details of the purity, quality and filtration standards for oxidant air.

(f) Evidence that the fuel reformer can meet fuel purity and composition requirements.

(g) Details of maximum and minimum allowable temperatures and pressures for the fuel reformer and expected temperatures and pressures during normal and reasonably foreseeable abnormal conditions.

(h) Details of cooling and/or heating requirements for the fuel reformer.

(i) Details of maximum allowable vibration, shock loading and impact which the fuel reformer is intended.

3.3.2 The documentation described below is to be submitted for appraisal:

(a) Details of the arrangements for the supply and conditioning of fuel and oxidant, including manifolds, trunking, fans and filtering and any necessary cleaning.

(b) Fuel piping system plans including details of the piping design, materials, installation, ducting, valves, fittings, pressure relief, expansion, ventilation and purging arrangements.

(c) Fuel reformer plans including materials, pumps, compressors, heat exchangers, process tanks, reaction vessels, catalytic conversion, and any other machinery and equipment forming a part of the fuel reforming system.

(d) Details of oxidant air intakes, trunking and fans.

(e) Purging and inerting arrangements.

3.4 Fuel cell module

3.4.1 The documentation described below is to be submitted for information:

(a) Description of fuel cell modules including associated fuel cell stack arrangement.

(b) Evidence of testing in accordance with a recognised international or national type testing standard.

(c) Details of the toxicity, corrosivity, flammability and reactivity of fuel cell stack materials, electrolyte, catalytic oxidants, condensate and other substances within the fuel cell module.

(d) Details of the expected fuel cell stack temperatures and pressures in normal operation and under reasonably foreseeable abnormal conditions.

(e) Details of the maximum and minimum temperatures and pressures for fuel, oxidant and services required by the fuel cell stacks.

(f) Details of the composition of fuel cell module exhaust gas and condensate.

(g) Details of cooling and/or heating requirements.

3.4.2 The documentation described below is to be submitted for appraisal:

(a) Plans of fuel cell modules, including fuel cell stacks, connections for fuel, oxidant, water and any other service fluids/gases, condensate, cooling, and flue gas.

(b) Plans and details of all penetrations in the fuel cell module.

3.5 Thermal management, water and condensate

3.5.1 The documentation described below is to be submitted for information:

(a) Plans and process flow drawings of exhaust piping, heat rejection and recovery equipment.

3.5.2 The documentation described below is to be submitted for appraisal:

(a) Plans of fuel cell power installation cooling/heating water and condensate equipment including materials, pumps, heat exchangers, tanks, condensate process equipment, and other machinery and equipment fitted for the supply, discharge and processing of water and condensate.

(b) Plans of cooling/heating water and condensate piping systems including installation, materials, ducting, valves and fittings, pressure relief, expansion, draining and purging arrangements.

(c) Details of the exhaust back pressure and the maximum allowable back pressure of the fuel cell module where thermal conditioning equipment is included within fuel cell power system exhaust arrangements.

3.6 Electrical and control equipment

3.6.1 The documentation described below is to be submitted for information:

(a) Evidence of testing in accordance with LR Type Approval System – Test Specification Number 1 or recognised international or national type testing standard, as appropriate to its location.

(b) A Factory Acceptance Test plan which verifies the suitability and correct operation of the electronic control and safety system during both normal and reasonably foreseeable abnormal operation.

(c) A schedule of the estimated operational loads on the system for the different operating conditions expected. The fuel cell module service profile is to include requirements for maximum allowable rate of temperature increase and any limitations on load cycling.

3.6.2 The documentation described below is to be submitted for appraisal:

(a) Line diagram of the installation(s) indicating the rating of the various items of rotating machinery, converters, transformers and protective devices, together with the types and sizes of cables and the makes, types and ratings of protective devices.

(b) Arrangement plans and circuit diagrams of the switchboards.

(c) Calculations for short-circuit currents.

(d) A schedule of electrical equipment located in hazardous zones, giving details of the type of equipment employed, the Certifying Authority and the certificate number.

(e) Details of high voltage electrical and/or optical fibre cable routing and details of cable glands and sheathing.

(f) Plan for software production.

(g) Line diagrams and details of the control system.

(h) Schedule of the parameters which are monitored and controlled, including alarms and shutdown devices.

(i) A cause and effect diagram indicating the causes and results of activation of all shutdowns associated with the fuel cell power installation.

3.7 Fire protection, detection and extinction

3.7.1 The documentation described below is to be submitted for information:

(a) Details of any special fire-extinguishing media required by the fuel cell power system and associated fuel and oxidant supply systems, or details of any hazards presented from using water or other standard fire-extinguishing media on any part of the fuel cell power system.

(b) A fire control plan meeting the requirements of SOLAS Chapter II-2, Regulation 15.2.4, along with a structural fire protection plan.

(c) A plan showing the arrangement of the fire main system protecting all fuel cell spaces, or spaces adjacent to any part of the fuel cell power system.

3.7.2 The documentation described below is to be submitted for appraisal:

(a) A plan showing the arrangement of waterspray systems protecting spaces containing any part of the fuel cell power system, fuel and oxidant supply to the fuel cell power system, fuel and oxidant storage hold spaces and ventilation trunks to such spaces, if any. The plan is to show details of any such fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

(b) A plan showing the arrangements of the fire detection system for the fuel cell power installation.

■ *Section 4*
Design principles for fuel cell power installations

4.1 Fuel cell power installation

4.1.1 Fuel cell power installations are to be suitable for the service profile and Design Statement as required by these Rules.

4.1.2 The design of fuel cell power installations shall comply with industry standards, such as IEC 62282-2 *Fuel cell technologies - Part 2-100: Fuel cell modules – Safety* and IEC 62282-3-100 *Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety* and *62282-3-100 Stationary fuel cell power systems - Safety*, or at least equivalent to those acceptable to Lloyd's Register (hereinafter referred to as LR).

4.1.3 Where fuel cell power installations supply power for propulsion of the ship or other essential services they are to satisfy the corresponding requirements relating to essential machinery and equipment in *Pt 5 Main and Auxiliary Machinery* and the requirements for power supplies for main or emergency services of *Pt 6, Ch 2 Electrical Engineering*.

4.1.4 Where fuel cell power installations which supply power for propulsion of the ship or other essential services rely on auxiliary ship services such as cooling water, compressed air, etc. loss of the auxiliary service is not to result in a loss of power for propulsion or power for other essential services.

4.1.5 Where power for propulsion of the ship or other essential services is provided entirely by fuel cell power installations, no fewer than two fuel cell power installations are to be provided so that one fuel cell power installation is retained in operation or is capable of being brought into operation in the event of a failure of the other. The capacity is to be such that in the event of any one fuel cell power installation being stopped it will be possible to supply those services necessary to provide essential services necessary for propulsion and safety, as applicable.

4.1.6 Where power for propulsion of the ship or other essential services is provided entirely by fuel cell power installations, means are to be provided to ensure that the fuel cell power installations can recover from black out and be brought into operation from the dead ship condition without external aid. Where batteries are used to provide the means of recovery, the batteries are to be protected against depletion when not in use.

4.1.7 Where fuel cell power installations are to be connected to a DC distribution system or a hybrid electrical power system incorporating other sources of electrical power, the equipment is also to satisfy the relevant requirements of *Pt 6, Ch 2, 24 Hybrid electrical power systems*.

4.2 Fuel cell power installation – Fuel cell power system

4.2.1 A single failure of any part of the fuel cell power system is not to result in a hazardous release into a non-hazardous area.

4.2.2 The fuel cell power system shutdown and fuel supply isolation are to be capable of being performed locally and from a position outside the fuel cell space which will always be easily accessible even in the event of fire occurring in that space.

4.2.3 Exhaust gases and exhaust air from the fuel cell power systems shall not be combined with any ventilation except ventilation serving fuel cell spaces and shall be led to a safe location in the open air.

4.2.4 Filters which could cause a failure of the fuel cell power system if blocked are to be provided with differential pressure monitoring and a stand-by filter unit. High differential pressure is to initiate an alarm.

4.2.5 Where any part of the fuel cell power system is susceptible to attack or degradation from airborne contaminants typical of the marine environment, arrangements for filtering and drying or closed air circulation are provided to ensure that the required air quality is in accordance with the fuel cell module manufacturer's requirements. Any parts of the system sensitive to air quality are to be sealed.

4.2.6 Where any exposed part of the fuel cell power system exceeds 220°C in normal operation or under reasonably foreseeable abnormal conditions the exposed surfaces are to be cooled or efficiently lagged so as to minimise the risk of fire or harm.

4.2.7 Means to safely remove the primary and reformed fuel from the fuel cell power system shall be provided.

4.2.8 Means shall be provided to set a fuel cell power installation into a safe state for maintenance and shutdown.

4.2.9 All pipes containing reformed fuel for fuel cell power systems, where fitted, are to be provided with fixed hydrogen detectors which are capable of detecting a hydrogen leak for places where leakage of hydrogen may occur, such as valves, flanges and seals.

4.2.10 For the auxiliary systems of the fuel cell power system where primary fuel or reformed fuel may leak directly into a system medium (e.g. cooling water), such auxiliary systems shall be equipped with appropriate extraction and detection means fitted as close as possible after the media outlet from the system in order to prevent gas dispersion. Gas extracted from the auxiliary system media shall be vented to a safe location on the open deck.

4.3 Fuel cell power installation – Fuel cell modules

4.3.1 Fuel cell modules are to satisfy the testing requirements of a recognised international or national type testing standard as agreed by LR.

4.3.2 Fuel cell modules are to be protected against overpressure, and over- and under-temperature.

4.3.3 Arrangements are to allow purging of flammable gases or vapours and inerting of the fuel cell modules.

4.3.4 Fuel and oxidant supplies to the fuel cell modules are to be in accordance with the fuel cell module manufacturer's requirements and are to be provided with a means of monitoring the flow, temperature and pressure of the fuel and oxidant supplied.

4.3.5 Arrangements are to prevent reverse flow of fuel and oxidant from the fuel cell modules back to the supply.

4.3.6 Fuel cell modules which utilise electrolytic fluids that are corrosive, flammable or otherwise harmful at high temperatures are to be provided with a means of monitoring the temperature of the electrolyte.

4.3.7 Exhaust arrangements are to convey exhaust gas from the fuel cell modules to a safe location on deck.

4.3.8 Arrangements are to prevent cross flow of exhaust gases between fuel cell modules.

4.3.9 Exhaust arrangements are to prevent water entering the fuel cell module and, where the possibility of condensate accumulating exists, the arrangements are to prevent the backflow of condensate to the fuel cell module and provide for condensate removal.

4.3.10 Exhaust temperature and flammable gas detection is to be provided for the fuel cell modules. An alarm is to be given at a gas concentration of 20 per cent LEL and the fuel cell module is to be shut down at a concentration of 40 per cent LEL.

4.4 Fuel cell power installation – Fuel reformer

4.4.1 A fuel reformer may supply fuel to multiple fuel cell modules, in which case the fuel reformer and the fuel cell modules which it supplies are considered to be a single fuel cell power system.

4.4.2 Fuel reformers are to be positioned as close to fuel cell modules as practicable.

4.4.3 Fuel reformers are to be automatic in operation and supply reformed fuel with defined composition and purity which is to be in accordance with the fuel cell module manufacturer's requirements.

4.4.4 It is to be possible to shut down fuel reformers from an easily accessible location outside the space in which they are located, at the control position and at a position in a remote safe area.

4.4.5 Shutdown arrangements are to shut off the primary fuel and are to be of the double block and bleed type. Alternative arrangements will be considered if supported by an engineering and safety statement.

4.4.6 Arrangements are to allow purging of flammable gases or vapours from the fuel reformers.

4.4.7 Where fuel reformers incorporate fuel combustion equipment the fuel combustion equipment is to be of an approved type.

4.4.8 Fuel reformers utilising services from the ship's supply such as cooling water, compressed air, etc. are to be compatible with expected variations in the ship's supply and are to include arrangements to prevent reverse flow back to the supply.

4.4.9 The arrangement of any safety and pressure relief discharges from fuel reformers is to ensure that no possibility of mixing which may result in a hazardous reaction between the primary fuel and the reformed fuel or any by-products formed in the reforming process.

4.4.10 Where provision is made to isolate pressure relief valves from vessels and piping systems for maintenance purposes, not less than two relief valves are to be fitted and the isolating arrangements are to ensure that one relief valve remains in communication with the fuel reformer under all conditions.

4.5 Fuel cell power installation – Power conditioning system

4.5.1 Converter equipment forming part of the fuel cell power conditioning equipment is to satisfy the relevant requirements of *Pt 6, Ch 2, 10 Converter equipment.*

4.5.2 The electrical output of fuel cell modules is to meet the service profile and Design Statement. Each fuel cell power system is to be provided with power conditioning equipment which is to be suitable for continuous duty at its full rated output at the maximum allowable cooling air or water temperature for an unlimited period, without the limits of temperature rise stated in the Design Statement being exceeded.

4.5.3 A single power conditioning system may provide power conditioning for more than one fuel cell module provided that there is an effective means of disconnecting each fuel cell module from the power conditioning equipment. In such cases the fuel cell modules are to be considered part of the same fuel cell power installation.

4.5.4 Where power conversion equipment is fitted to a fuel cell power system to supply alternating current, power supply quality requirements are to be defined and the requirements for hybrid electrical power systems shall be applied as applicable.

4.5.5 Fuel cell modules which operate in parallel with conventional rotating electrical generators are to satisfy the provisions of *Pt 5, Ch 26, 4.5 Fuel cell power installation – Power conditioning system 4.5.6* and *Pt 5, Ch 26, 4.5 Fuel cell power installation – Power conditioning system 4.5.7* when operating in this configuration.

4.5.6 Power conditioning equipment supplying electrical power to the distribution bus and consumers is to be capable of delivering the required currents for discrimination purposes to downstream protective devices, and automatically maintaining the supply of power and voltage to consumers after fault clearance without sustaining any damage.

4.5.7 Fuel cell modules which are to operate in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any fuel cell module does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest fuel cell module or 25 per cent of the rated output (kW) of the individual module, whichever is less.

4.5.8 When fuel cell modules are operated in parallel, the kVA loads of the individual fuel cell modules are not to differ from the proportionate share of the total kVA load as stated and justified by the system integrator and/or fuel cell manufacturer.

4.5.9 There is to be a means of preventing reverse power to the fuel cell stacks. This is to ensure that the fuel cell stack manufacturer's maximum allowable duration and levels of reverse power flow are not exceeded.

4.5.10 Means shall be provided for protection of the fuel cell installation against short circuits and flow of reverse current.

4.6 Fuel cell power installation – Thermal management system

4.6.1 A thermal management system which provides cooling, heating, humidity management and condensate removal where required by the fuel cell modules is to be provided.

4.6.2 Thermal conditioning equipment utilising services from the ship's supply such as cooling water, compressed air, etc. is to be compatible with expected variations in the ship's supply and is to include arrangements to prevent reverse flow back to the supply.

4.6.3 Loss of fuel cell coolant shall result in an automatic shutdown of the fuel cell by the process control within a limited period of time. To prevent a potential coolant release in the fuel cell space, a secondary containment of the coolant pipe should be provided or the equipment within the fuel cell space should be protected from a coolant release. Consideration should be given to the safe removal of the coolant.

4.6.4 Where thermal conditioning equipment is fitted to the fuel cell power system exhaust, the resulting back pressure is to remain within the allowable limit of the fuel cell module.

4.6.5 A means of collecting and storing any condensate produced by the fuel cell power system is to be provided. Substances which react if mixed are to be provided with separate and distinct condensate drainage arrangements.

4.6.6 Condensate collection piping, collection tank and transfer arrangement are to be suitable for the composition of condensate.

4.6.7 Where the condensate collection tank is arranged such that more than one fuel cell module delivers condensate to the tank, each fuel cell module is to have a separate feed to the collection tank or, alternatively, the condensate collection piping is to incorporate a means of preventing the cross flow of condensate between fuel cell modules.

4.6.8 Where primary fuel or reformed fuel may leak directly into the thermal conditioning equipment, the equipment is to be provided with appropriate extraction and detection means fitted as close as possible after the media outlet from the equipment. Gas extracted is to be vented to an appropriately designated location on the open deck.

4.7 Fuel cell power installation – Purging system

4.7.1 Provision is to be made for purging the fuel cell power system of flammable gases and vapours using an inert gas.

4.7.2 Inert gas for purging may be generated on board or supplied from an inert gas storage system with provision for refilling from ashore.

4.7.3 Where the inert gas is generated on board, the design of the inert gas generator is to ensure that inert gas meets the specified composition and purity requirements.

4.7.4 Where the inert gas is not generated on board the storage capacity is to be derived from the service profile and Design Statement.

4.7.5 Where fuel cell modules require purging to be carried out using a mixture of inert gas and flammable gas in order to avoid damage to fuel cell modules, the purging gas mixture is not to present a hazard during normal and reasonably foreseeable abnormal operating conditions.

4.8 Fuel cell power installation – Control, Monitoring and Safety system

4.8.1 Safety related parts of the fuel cell control systems shall be designed to be independent from any other control and monitoring systems or shall comply with the process as described in industry standards acceptable to LR for the performance level or equivalent.

4.8.2 The fuel cell should be monitored according to the manufacturer's recommendations.

4.8.3 Fuel cell power installations shall be designed for automatic operation and equipped with all the monitoring and control facilities required for safe operation of the system. These facilities may be provided at the ship's main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

4.8.4 Chemical reactions, such as those taking place during fuel reforming, if fitted, or within the fuel cell modules, are to be monitored at the control station, e.g. by means of temperature, pressure or voltage monitoring.

4.8.5 Alarms are to be provided to notify of abnormal conditions and faults.

4.8.6 As a minimum, alarms are to be provided in accordance with *Table 26.4.1 Fuel cell power installation alarms and safeguards*. A justification is to be provided for any items considered not applicable to the fuel cell installation.

4.8.7 Alarms additional to the ones required by *Table 26.4.1 Fuel cell power installation alarms and safeguards* may be recommended for unconventional or complex fuel cell power installations.

4.8.8 If limit values determined for the control process (e.g. temperature, pressure, voltage, gas concentrations) which may lead to hazardous situations are exceeded, then the fuel cell power system is to be automatically shut down and interlocked by a fuel cell safety system.

4.8.9 Safeguards, including shutdowns, to be provided are to take account of any related requirements or recommendations from the engineering and safety justification. As a minimum, safeguards are to be provided in accordance with *Table 26.4.1 Fuel cell power installation alarms and safeguards*. A justification is to be provided for any items considered not applicable to the fuel cell installation.

4.8.10 Safeguards additional to the ones required by *Table 26.4.1 Fuel cell power installation alarms and safeguards* may be recommended for unconventional or complex fuel cell power installations.

4.8.11 It shall be possible to shut down the fuel cell power system from an easily accessible location outside the fuel cell spaces.

4.8.12 The output voltage, current and frequency (where applicable) of the fuel cell power installation are to be displayed at the control station for the fuel cell power installation.

4.8.13 The output voltage and current of each fuel cell module and the output voltage and current at the outlet of power conditioning equipment are to be displayed at the control station for the fuel cell power installation.

Table 26.4.1 Fuel cell power installation alarms, safeguards

Item	Alarm	Fuel supply isolation	Fuel cell power system shutdown	Note	Reference
Fire detection	A	X	X	1, 8	*Pt 5, Ch 26, 1.2 Functional requirements 1.2.14*, *Pt 5, Ch 26, 6.3 Fire detection 6.3.5*, *Pt 5, Ch 26, 6.3 Fire detection 6.3.6*
Gas detection 20% LEL	HA			1	*Pt 5, Ch 26, 4.12 Fuel cell space – Arrangement 4.12.8*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.8*
Gas detection 40% LEL at 2 detectors	HHA	X	X	1, 9	*Pt 5, Ch 26, 4.12 Fuel cell space – Arrangement 4.12.9*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.8* *Pt 5, Ch 26, 5.2 Piping and pressurised equipment and components 5.2.2 (d)*

Hydrogen leakage at valves, flanges, seals	A				*Pt 5, Ch 26, 4.2 Fuel cell power installation – Fuel cell power system 4.2.9*
Gas detection in the secondary enclosure of pipes	HA	X			*Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.8*
Liquid detection in fuel cell space	A	X	X		*Pt 5, Ch 26, 4.9 Fuel cell space 4.9.5*, *Pt 5, Ch 26, 4.12 Fuel cell space – Arrangement 4.12.3*
Level of bilge wells in fuel cell space	HA				*Pt 5, Ch 26, 4.12 Fuel cell space – Arrangement 4.12.4*
Failure of one ventilation fan	A			2	*Pt 5, Ch 26, 4.13 Fuel cell space – Ventilation 4.13.3*
Loss of ventilation or loss of negative pressure in fuel cell space	LA	X		3, 10	*Pt 5, Ch 26, 4.13 Fuel cell space – Ventilation 4.13.5*, *Pt 5, Ch 26, 4.13 Fuel cell space – Ventilation 4.13.6*
Fuel cell space inerting (if applicable) medium pressure	LA	X	X	3	*Pt 5, Ch 26, 4.14 Fuel cell space – Inerting 4.14.1 (c)*, *Pt 5, Ch 26, 4.14 Fuel cell space – Inerting 4.14.1 (d)*
Airlock alarms as per IGF Code Regulation 5.12	A				*Pt 5, Ch 26, 4.11 Fuel cell space – Access 4.11.1*
Differential cell pressure	HA			4	*Pt 5, Ch 26, 4.2 Fuel cell power installation – Fuel cell power system 4.2.4*
Flammable gas in auxiliary systems	A				*Pt 5, Ch 26, 4.2 Fuel cell power installation – Fuel cell power system 4.2.4*, *Pt 5, Ch 26, 4.6 Fuel cell power installation – Thermal management system 4.6.8*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.10*
Fuel cell module pressure	HA				*Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.2*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5*
Fuel cell module pressure	HHA		X		*Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.2*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4*,

					Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5
Fuel cell module temperature	LA, HA			5	Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.2, Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4, Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5, Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5
Fuel cell module temperature	LLA, HHA		X	5	Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.2, Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4, Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5, Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5
Fuel and oxidant supply flow, temperature, pressure	LA, HA				Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.4
Fuel and oxidant supply flow, temperature, pressure	LLA, HHA	X	X		Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.4
Fuel cell stack surface temperature >300°C	HA			11	Pt 5, Ch 26, 4.9 Fuel cell space 4.9.6
Fuel cell stack surface temperature >300°C	HHA	X	X	11	Pt 5, Ch 26, 4.9 Fuel cell space 4.9.6
Fuel cell module electrolyte temperature	HA			6	Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.6
Fuel cell module electrolyte temperature	HHA		X	6	Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.6
Fuel cell module exhaust temperature	HA				Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.10, Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5
Fuel cell module exhaust temperature	HHA		X		Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.10, Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system

					equipment and components 5.5.5
Fuel cell module exhaust gas detection 20% LEL	HA				*Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.10*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.11*
Fuel cell module exhaust gas detection 40% LEL	HA	X	X		*Pt 5, Ch 26, 4.3 Fuel cell power installation – Fuel cell modules 4.3.10*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.11*
Fuel cell module voltage, current	OoR				*Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.13*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5*
Fuel cell coolant level, pressure	LA		X	3, 7	*Pt 5, Ch 26, 4.6 Fuel cell power installation – Thermal management system 4.6.8* *Pt 5, Ch 26, 4.12 Fuel cell space – Arrangement 4.12.12*
Loss of fuel cell coolant	A	X			*Pt 5, Ch 26, 6.3 Fire detection 6.3.5*
Reformed fuel composition, purity (if reforming applicable)	OoR				*Pt 5, Ch 26, 4.4 Fuel cell power installation – Fuel reformer 4.4.3*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5*
Reforming temperature, pressure (if reforming applicable)	OoR				*Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.4*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.5*
Power conditioning cooling air or water temperature	HA				*Pt 5, Ch 26, 4.5 Fuel cell power installation – Power conditioning system 4.5.2*
Power conditioning output voltage, current and frequency	OoR				*Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.12*,

					Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.13, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5*
Emergency release button	A	X	X		*Pt 5, Ch 26, 4.2 Fuel cell power installation – Fuel cell power system 4.2.2*, *Pt 5, Ch 26, 4.4 Fuel cell power installation – Fuel reformer 4.4.4*, *Pt 5, Ch 26, 4.8 Fuel cell power installation – Control system 4.8.13*, *Pt 5, Ch 26, 4.9 Fuel cell space 4.9.6*, *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.5*

Note 1. Detection at all locations required by the Rules.
Note 2. Automatic changeover.
Note 3. Shutdown within a limited period of time.
Note 4. All filters which if blocked could cause failure of the fuel cell power system.
Note 5. Low temperature may be omitted if agreed to by LR.
Note 6. For electrolytic fluids which are corrosive, flammable or harmful at high temperature.
Note 7. Cooling water may be monitored at a single point on the supply circuit to fuel cell power system components where supplied by a common system.
Note 8. Shutdown of ventilation, release of fire-extinguishing system.
Note 9. If not certified for operation in Zone 1 hazardous areas, the fuel cell stack should be immediately electrically isolated and de-energised
Note 10. The fuel cell should be automatically shut down by process control
Note 11. If fuel cell stack is not certified for Zone 1

A Logical alarm
HA, LA 1st stage high, 1st stage low
HHA, LLA 2nd stage high, 2nd stage low
OoR Out of range

4.9 Fuel cell space

4.9.1 In order to minimise the probability of a gas explosion in a fuel cell space, the space shall meet the requirements of this sub-Section, or an equivalent safety concept.

4.9.2 The fuel cell space concept is such that the space is designed to mitigate hazards to non-hazardous levels under normal conditions, but under certain abnormal conditions may have the potential to become hazardous.

4.9.3 In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of equipment and components that are not suitably certified safe type for the hazards concerned is to be automatically executed, while equipment or components in use or active during these conditions are to be of a suitably certified safe type.

4.9.4 The fuel cell space is to comply with at least one of the following safety concepts identified and detailed in *Pt 5, Ch 26, 4.9 Fuel Cell Space 4.9.7*.

4.9.5 Detection of liquids shall interrupt the fuel supply to the fuel cell space and de-energise the ignition sources inside the fuel cell space.

4.9.6 Actuation of the emergency shutdown push button shall interrupt the fuel supply to the fuel cell space and de-energise the ignition sources inside the fuel cell space.

4.9.7 For equipment protection in fuel cell spaces the following options can be considered:

- As an outcome of hazardous area classification according to *Pt 5, Ch 26, 5.4 Electrical equipment and components 5.4.5*, such fuel cell spaces are considered as hazardous Zone 1 and all electrical equipment in the space shall be certified for Zone 1. The fuel cell stack itself is not considered a source of ignition if the surface temperature of the stack is kept below 300°C (see note) in all operating conditions and the fuel cell power system should be capable of immediately isolating and de-energizing the fuel cell stack under every load and operating condition. Note: the 300°C threshold is taken from ISO/IEC 80079-20-1 *Explosive*

atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data, where the maximum surface temperature is set to 450°C for Hydrogen and LNG and 300°C for methyl/ethyl alcohol and LPG. To ensure safe operation of fuel cell power systems regardless of the fuel cell and fuel type, these guidelines refer to the lowest threshold for the relevant fuels mentioned in the ISO/IEC 80079-20-1 *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*, that is 300°C.

- In specific cases where LR considers the prescriptive area classification to be inappropriate, area classification according to IEC 60079-10-1 *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres* shall be applied according to *Pt 5, Ch 26, 5.4 Electrical equipment and components 5.4.4*, taking into account the following guidance: All electrical equipment shall comply with the resulting area classification.
- In specific cases where LR and the Administration accepts inerting according to *Pt 5, Ch 26, 4.1 Fuel cell space - Inerting 4.14*, the following guidance shall be taken into account: As ignition hazards are mitigated by inerting, there is no need for an immediate (emergency) shutdown of the fuel supply in case of leakage detection. In case of leakage detection, automatic changeover to the standby power supply systems shall take place and a controlled shutdown of the fuel cell and the affected fuel supply system shall be initiated in order, thereby avoiding damage to the fuel cell power system.

4.9.8 Protection of fuel cell spaces by an external boundary that encloses components where fuel is fed shall be achieved by ventilation or inerting. These methods should be equally acceptable to ensure the safety of the space.

4.9.9 Within the fuel cell space concept, a single failure may result in a release of primary fuel, reformed fuel or hazardous gases into the space. Ventilation or inerting, if required, are to be designed to accommodate a probable maximum leakage scenario due to technical failures.

4.9.10 Failures leading to dangerous gas concentrations (e.g. gas pipe ruptures or blow out of gaskets) are to be covered by explosion pressure relief devices and ESD arrangements.

4.9.11 Fuel cell spaces containing fuel reformers shall also comply with the requirements relevant for the primary fuel.

4.10 Fuel cell space – Location

4.10.1 Fuel cell spaces shall be arranged outside of accommodation spaces, service spaces, machinery spaces of category A and control stations.

4.10.2 Proposals for locating fuel cell spaces within machinery spaces of category A may be specially considered.

4.11 Fuel cell space – Access

4.11.1 Where an independent and direct access to the fuel cell spaces from the open deck cannot be arranged, access to fuel cell spaces is to be through an airlock compliant with the IGF Code 5.12 Regulations for airlocks.

4.11.2 Subject to agreement by the National Administration, consideration will be given to direct access from a non-hazardous area to a Zone 2 hazardous area where the Zone 2 area has a bolted hatch that provides direct access into the space.

4.11.3 An airlock is not required if appropriate technical provisions are made such that access to the space is not required and not made possible before the equipment inside is safely shut down, isolated from the fuel system and drained of leakages, and the inside atmosphere is confirmed to be gas-free, or otherwise the space is consider non-hazardous under all conditions.

4.11.4 These provisions include but are not limited to:

(a) all controls required for safe operation and gas freeing of the equipment and space shall be provided for remote operation from outside the space;

(b) all parameters required for safe operation and gas freeing shall be remotely monitored and alarms shall be given;

(c) the space openings shall be equipped with an interlock preventing operation with the space open;

(d) the spaces shall be provided with suitable fuel leakage collection and draining arrangements for remote operation from outside the space; and

(e) provisions shall be made that the fuel equipment inside can be isolated from the fuel system, drained of fuel and purged safely for maintenance.

4.11.5 Escape routes from the fuel cell space are not to pass through hazardous areas.

4.12 Fuel cell space – Arrangement

4.12.1 Fuel cell space boundaries shall be gastight towards other enclosed spaces in the ship.

4.12.2 Piping and cabling penetrations within the boundaries of fuel cell spaces are to be approved gastight.

4.12.3 Arrangement shall be provided to rapidly detect leakages of liquid primary fuel inside the fuel cell space.

4.12.4 Detection of unintended liquid leakages in the fuel cell space should trigger an alarm. A possible means of detection would be a bilge high-level alarm.

4.12.5 An alarm shall be activated for high liquid levels in bilge wells.

4.12.6 Fuel cell spaces are to be designed to safely contain fuel leakages and be provided with suitable leakage detection systems and should be arranged to avoid the accumulation of hydrogen-rich gas (*see also* IEC 60079-10-1 *Explosive atmospheres – Part 10-*

1: Classification of areas – Explosive gas atmospheres) by having simple geometrical shape and no obstructing structures in the upper part.

4.12.7 Leakage detection is to be indicated by an alarm.

4.12.8 Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 20 per cent LEL shall cause an alarm.

4.12.9 Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 40 percent LEL should shut down the affected fuel cell power system and disconnect ignition sources and should result in automatic closing of all valves required to isolate the leakage. If not certified for operation in Zone 1 hazardous areas, the fuel cell stack should be immediately electrically isolated and de-energised. Valves in the primary fuel system supplying liquid or gaseous fuel to the fuel cell space should close automatically.

4.12.10 Fuel cell spaces shall be arranged to avoid the accumulation of hydrogen rich gas (*see* IEC 60079-10-1*: Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*) by having a simple geometrical shape that will minimise the accumulation of gases or formation of gas pockets and have no obstructing structures in the upper part.

4.13 Fuel cell space – Ventilation

4.13.1 Fuel cell spaces shall be equipped with an effective mechanical ventilation system to maintain underpressure of the complete space, taking into consideration the density of potentially leaking fuel gases.

4.13.2 For fuel cell spaces on open decks, overpressure ventilation may be considered.

4.13.3 Two or more fans shall be installed for the ventilation of the fuel cell space, providing 100 per cent redundancy upon loss of one fan. 100 per cent ventilation capacity is to be supplied from the emergency source of power.

4.13.4 In case of failure of one fan, automatic changeover to another fan shall be provided and indicated by an alarm.

4.13.5 In order to verify the performance of the ventilation system, a detection system of the ventilation flow and of the negative fuel cell space pressure shall be installed. A running signal from the ventilation fan motor is not sufficient to verify performance.

4.13.6 In case of loss of ventilation or loss of underpressure in the fuel cell space the fuel cell power system should carry out an automatic, controlled shutdown of the fuel cell and isolation of the fuel supply

4.13.7 Loss of ventilation in a fuel cell space shall result in an automatic shutdown of the fuel cell by the process control within a limited period of time. The period for the shutdown by the process control shall be considered on a case by case basis based on the risk analysis. After the period has expired, a safety shutdown should be carried out.

4.13.8 The ventilation rate in fuel cell spaces should be sufficient to dilute the average gas/vapour concentration below 25 per cent of the LEL in all maximum probable leakage scenarios due to technical failures.

4.13.9 Any ducting used for the ventilation of fuel cell spaces shall not serve any other space.

4.13.10 Ventilation ducts from spaces containing reformed fuel piping or release sources shall be designed and arranged such that any possibility for gas to accumulate is avoided.

4.13.11 In case of loss of ventilation or loss of negative pressure in the fuel cell space, the fuel cell power system shall carry out an automatic, controlled shutdown of the fuel cell and isolation of the fuel supply.

4.13.12 Ventilation air inlets for fuel cell spaces shall be taken from areas which, in the absence of the considered inlet, would be non-hazardous.

4.13.13 Ventilation air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas located at least 1,5 m away from the boundaries of any hazardous area.

4.13.14 Ventilation air inlets for fuel cell spaces are to be positioned below the lowest point from which hydrogen rich gas may leak.

4.13.15 Ventilation air outlets from fuel cell spaces are to be designed to prevent any accumulation of hydrogen rich gas within the duct and the number of bends is to be minimised.

4.13.16 Ventilation air outlets from fuel cell spaces shall be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

4.13.17 Fuel cell spaces or fuel cell power systems served by a common ventilation air inlet or a common ventilation air outlet are to be considered as being part of the same fuel cell power system.

4.13.18 Verification of the strength is to be based on calculation demonstrating the ducting integrity. As an alternative to calculations, the strength can be verified by representative tests.

4.14 Fuel cell space – Inerting

4.14.1 Inerting shall be accepted for atmospheric control of the fuel cell spaces provided that:

(a) protection by inerting is only acceptable where the fuel cell space cannot be entered during inerting and sealing arrangements shall ensure that leakages of inert gas to adjacent spaces are prevented;

(b) the inerting system complies with chapter 15 of the FSS Code and paragraphs 6.13 and 6.14 of the IGF Code;

(c) the pressure of inerting media is always kept positive and monitored;

(d) any change in the pressure, indicating a breach of the external outer boundary of the fuel cell space, or a breach of the boundary with a space in which fuel is flowing (e.g. fuel cell stack, reformer, etc.), shall activate a controlled shut-off of the fuel supply;

(e) the fuel cell space is equipped with a mechanical ventilation to evacuate the inerting agent, after an inerting release has been initiated;

(f) access to the inerted fuel cell space is only possible when the space is completely ventilated by fresh air and the fuel supply is interrupted and depressurised or purged; and

(g) the inerting system is not operable under ongoing maintenance or inspection.

■ *Section 5* Materials, equipment and components

5.1 Materials

5.1.1 In addition to the fuel cell specific requirements within these Rules, where fuel cell installations incorporate materials included in the *Rules for the Manufacture, Testing and Certification of Materials*, they are to satisfy the corresponding requirements therein.

5.1.2 The materials within the fuel cell power installation shall be suitable for the intended application and are to comply with recognised International or National Standards.

5.1.3 The use of combustible materials within the fuel cell power system shall be kept to a minimum.

5.1.4 For the control of electrostatic hazards, *see Pt 5, Ch 12, 5.2 Design and performance criteria 5.2.4*

5.1.5 Pipes, valves and other components for the containment of hydrogen or hydrogen rich gas are to be constructed of austenitic stainless steel. Other materials are subject to special consideration where they can be demonstrated to:

(a) be resistant to the chemical and physical action of hydrogen at the operating conditions, including consideration of hydrogen embrittlement and hydrogen attack;

(b) be suitable for the intended application, including consideration of hydrogen permeability, static accumulation and sparking;

(c) have hydrogen compatibility in accordance with a recognised International or National Standard (e.g. ASME B31.12 *Hydrogen Piping and Pipelines*); and

(d) comply with any specifications and test procedures considered necessary by LR.

5.2 Piping and pressurised equipment and components

5.2.1 In addition to the fuel cell specific requirements within these Rules, where fuel cell power installations incorporate piping components included in *Pt 5, Ch 12 Piping Design Requirements*, they are to satisfy the corresponding requirements therein.

5.2.2 All pipes containing reformed fuel for fuel cell power systems, where fitted, shall:

(a) not be led through enclosed spaces outside of fuel cell spaces;

(b) be fully welded as far as practicable;

(c) be arranged to minimise the number of connections; and

(d) use fixed hydrogen detectors which are capable of detecting a hydrogen leak in places where leakage of hydrogen may occur, such as valves, flanges and seals.

5.2.3 Piping sections containing fuel which are not open ended but can be isolated are to be provided with relief valves. Alternative arrangements may be considered where an equivalent level of safety can be demonstrated.

5.2.4 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In no case is the design pressure to be less than 10 barg except for open-ended piping where the minimum design pressure is to be 5 barg.

5.2.5 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

5.2.6 Low temperature piping is to be thermally isolated from the adjacent hull structure, where the piping temperature can be lower than the design temperature of the hull.

5.2.7 Piping is to demonstrate electrical continuity and be earth bonded to the hull.

5.2.8 Heat exchangers and evaporators are to be designed to prevent cross-contamination between the primary and secondary sides of the heat exchanger and are to incorporate an alarm and fuel supply shutdown in the event of cross-contamination.

5.2.9 Pumps are to be protected against running dry and protected against overpressure in the event that downstream lines are blocked, or downstream valves are closed.

5.2.10 Where connections and non-welded joints for piping are required, they are to be of an approved type and are to:

(a) be resistant to the chemical and physical action of hydrogen at the operating conditions, including consideration of hydrogen embrittlement and hydrogen attack;

(b) be suitable for the intended application, including consideration of hydrogen permeability, static accumulation and sparking;

(c) demonstrate hydrogen compatibility in accordance with a recognised International or National Standard (e.g. ASME B31.12 *Hydrogen Piping and Pipelines*); and

(d) comply with any specifications and test procedures considered necessary by LR.

5.3 Mechanical equipment and components

5.3.1 In addition to the fuel cell specific requirements within these Rules, where fuel cell power installations incorporate mechanical equipment and components included in *Pt 5 Main and Auxiliary Machinery*, they are to satisfy the corresponding requirements therein.

5.3.2 Mechanical equipment is not to be installed in hazardous areas unless essential for operational purposes or safety enhancement.

5.3.3 The design, arrangements and selection of mechanical equipment and components for use in hazardous areas are to minimise sources of ignition.

5.3.4 Mechanical equipment and components intended for use in a hazardous area are to be designed, constructed and installed to ensure that they are:

(a) capable of safe operation in normal and all reasonably foreseeable hazardous conditions;

(b) capable of preventing the formation of a hazardous and/or toxic atmosphere that may be produced or released by the components or equipment;

(c) capable of preventing the ignition of hazardous atmospheres, taking into account the nature of every electrical and non-electrical source of ignition; and

(d) appropriate for use in a hazardous area in accordance with a recognised International or National Standard, such as *ISO 80079-36 Non-electrical equipment for explosive atmospheres — Basic method and requirements*

5.4 Electrical equipment and components

5.4.1 In addition to the fuel cell specific requirements within these Rules, where fuel cell power installations incorporate electrical equipment and components included in *Pt 6, Ch 2 Electrical Engineering*, they are to satisfy the corresponding requirements therein.

5.4.2 Electrical equipment shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

5.4.3 Where electrical equipment including components of fuel cell power systems is installed in hazardous areas, it is be selected, installed and maintained in accordance with recognised International or National Standards such as IEC 60079-10 *Explosive atmospheres Part 10-1: Classification of areas – Explosive gas atmospheres* and guidance and informative examples given in IEC 60092-502, *Electrical Installations in Ships – Tankers – Special* features for tankers

5.4.4 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into Zones 0, 1 and 2, according to *Pt 5, Ch 26, 5.4 Electrical equipment and components 5.4.5*. In cases where the prescriptive provisions in *Pt 5, Ch 26, 5.4 Electrical equipment and components 5.4.5* are deemed to be inappropriate, area classification according to IEC 60079-10 *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres* shall be applied with special consideration by LR and the Administration.

5.4.5 Definition of zones

(a) Hazardous areas Zone 0. The following areas should be treated as hazardous area Zone 0:

the interiors of buffer tanks, reformers, pipes and equipment containing low-flashpoint fuel or reformed fuel, any pipework of pressure-relief or other venting.

(b) Hazardous areas Zone 1. The following areas should be treated as hazardous area Zone 1:

(i) areas on open deck or semi-enclosed spaces on deck within 3 m of any reformed fuel or purge gas outlets or fuel cell space ventilation outlets;

(ii) areas on open deck, or semi-enclosed spaces on deck, within 3 m of fuel cell exhaust air and exhaust gas outlets;

(iii) areas on open deck or semi-enclosed spaces on deck within 1,5 m of fuel cell space entrances, fuel cell space ventilation inlets and other openings into Zone 1 spaces;

(iv) areas on open deck or semi-enclosed spaces within 3 m of areas in which other sources of release of reformed fuel are located; and

(v) fuel cell spaces.

(c) Hazardous areas Zone 2. The following areas should be treated as hazardous area Zone 2:

(i) areas within 1,5 m surrounding open or semi-enclosed spaces of Zone 1 as specified above, if not otherwise specified; and

(ii) air locks.

5.4.6 Ventilation ducts are to have the same area classification as the ventilated space.

5.4.7 For fuel cell spaces rated as hazardous Zone 1 where the fuel cell stack is not certified for operation in hazardous Zone 1 and the surface temperature of the fuel cell stack exceeds 300°C, the fuel cell power system should immediately shut down and isolate the affected fuel cell space

5.5 Monitoring, control, alarm and safety system equipment and components

5.5.1 In addition to the fuel cell specific requirements within these Rules, where fuel cell power installations incorporate monitoring control, alarm and safety systems, equipment and components included in *Pt 6, Ch 1 Control Engineering Systems*, they are to satisfy the corresponding requirements therein.

5.5.2 For gas detection, requirements of the IGF Code section 15.8 are to be satisfied as appropriate as given in the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*.

5.5.3 The fuel cell shall be monitored appropriately to avoid any loss or degradation of its safety.

5.5.4 All operating conditions are to be monitored to verify that they are within the acceptable design range.

5.5.5 A Failure Mode and Effects Analysis (FMEA) shall be used to analyse and determine the extent of monitoring and control of the fuel cell power systems. The following shall be included as a minimum:

(a) voltage of fuel cells;

(b) temperature of exhaust gas and exhaust air;

(c) the internal temperature of the fuel cell. When the internal temperature reaches 80 per cent of the self-ignition temperature for the reformed fuel used, the load of the fuel cell shall be disconnected or reduced, or other cooling measures shall be taken;

(d) purity of the reformed fuel;

(e) output current; and

(f) contamination of air into fuel cell fuel lines, or of fuel cell fuel into air pipes.

5.5.6 The following monitoring shall be considered according to the type and working condition of the fuel cell:

(a) air flow;

(b) air pressure;

(c) flow rate, pressure and temperature of cooling medium;

(d) fuel flow;

(e) fuel temperature;

(f) fuel pressure;

(g) gas detection of exhaust fuel and exhaust air;

(h) liquid level of water system;

(i) pressure of water system;

(j) resistivity/conductivity of the water system;

(k) parameters necessary to monitor life time/deterioration of fuel cell; and

(l) balancing the air-to-fuel ratio in operation.

5.5.7 The fuel cell shall be provided with fault monitoring sensors to maintain the reaction process within the design limits.

5.5.8 A permanently installed gas/vapour detection system shall be provided for:

(a) fuel cell spaces;

(b) airlocks (if any);

(c) expansion tanks/degassing vessels in the auxiliary systems of the fuel cell power system where primary fuel or reformed fuel may leak directly into a system medium (e.g. cooling water); and

(d) other enclosed spaces where primary/reformed fuel may accumulate.

(e) Ventilation outlets, if required, as per *Pt 5, Ch 26, 5.5 Monitoring, control, alarm and safety system equipment and components 5.5.9.*

5.5.9 The detection systems shall continuously monitor for gas/vapour. The number of detectors in the fuel cell space shall be considered taking size, layout and ventilation of the space into account. The detectors shall be located where gas/vapour may accumulate and/or in the ventilation outlets. Gas dispersal analysis or a physical smoke test shall be used to find the best arrangement.

5.5.10 Gas/vapour detection shall be provided in the fuel cell's coolant supply/header tank, and this should cause an alarm.

5.5.11 Gas/vapour detection shall be provided at the process air outlet exhaust, and this should cause an alarm.

5.5.12 Gas/vapour detection shall be provided in the inter-barrier spaces, and this should cause an alarm.

5.5.13 Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of the self-monitoring type, the installation of a single gas detector can be permitted.

5.5.14 Manual activation of emergency shutdown shall be arranged in the following locations as applicable:

(a) navigation bridge;

(b) onboard safety centre;

(c) engine control room;

(d) fire control station; and

(e) adjacent to the exit of the fuel cell space.

■ *Section 6* Fire and explosion safety

6.1 Fire protection

6.1.1 The fuel cell space shall be regarded as a machinery space of category A according to SOLAS Chapter II-2 for fire protection purposes.

6.1.2 A fuel cell space shall be bounded by A-60 class divisions. Where this is deemed to be impracticable, LR and the Administration may approve alternative boundary designs that provide for an equivalent level of safety.

6.1.3 The fire-extinguishing system is to be suitable for use with the specific fuel and fuel cell technology. LR and the Administration may allow any alternative fire safety measures if the equivalence of the measure is demonstrated by a risk assessment considering the characteristics of fuels for use.

6.1.4 Where any part of the fuel cell power system is intended to operate with a continuous leakage of hydrogen rich gas, the fire and safety provisions are to be derived from the engineering and safety justification, as identified in *Pt 5, Ch 26, 2.1 Risk Assessment, 2.1.7*.

6.2 Explosion prevention and protection

6.2.1 Fuel cell spaces separated by a single bulkhead shall have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

6.2.2 Failures leading to dangerous overpressure, e.g. gas pipe ruptures or blow out of gaskets, shall be mitigated by suitable explosion pressure relief devices and ESD arrangements.

6.2.3 The probability of a gas accumulation and explosion in fuel cell spaces shall be minimised by one or more of the following strategies:

(a) purging the fuel cell power system before initiating the reaction;

(b) purging the system as necessary after shutdown;

(c) providing failure monitoring in the fuel cell fuel containment systems;

(d) monitoring potential contamination of air into fuel cell fuel lines, or of fuel cell fuel into air pipes;

(e) monitoring pressures and temperatures;

(f) implementing a pre-programmed sequence to contain or manage the propagation of the reaction to other sections of the fuel cell system or to the surrounding space; and

(g) any other strategy proposed by the manufacturer to the satisfaction of LR.

6.3 Fire detection

6.3.1 A fixed fire detection and fire alarm system complying with the International Code for Fire Safety Systems (FSS Code) shall be provided.

6.3.2 A fire detection and alarm system, satisfying the requirements of *Pt 6, Ch 1, 2.8 Fire detection and fire alarm systems* is to be fitted in all spaces containing potential sources of flammable fuel leakage and ignition.

6.3.3 The type and arrangement of the fire detection system shall be selected with due consideration of the reformed fuels and combustible gases which may be present in fuel cell power installations.

6.3.4 Fuel cell spaces shall be fitted with suitable fire detectors (note: for the selection of suitable fire detectors, ISO/TR 15916 *Basic considerations for the safety of hydrogen systems* can be taken into account). Smoke detectors alone are not considered sufficient for rapid detection of a fire when gaseous fuels are used. For the selection of suitable fire detectors, ISO/TR 15916 *Basic considerations for the safety of hydrogen systems* can be taken into account.

6.3.5 Fire detection within the fuel cell space should initiate automatic shutdown and isolation of the fuel supply.

6.3.6 Fire detection is to be arranged such that the activation of any fire detectors in, or adjacent to, hazardous areas or spaces containing gaseous, cryogenic liquid, toxic, corrosive or liquid fuels with a flash point below 60°C will automatically shut down any part of the fuel cell power system within or adjacent to such spaces.

6.4 Fire extinguishing

6.4.1 A fixed fire-extinguishing system shall be required for fuel cell spaces.

6.4.2 The fire-extinguishing system shall be suitable for use with the specific primary and reformed fuel and fuel cell technology proposed.

6.4.3 Fixed fire-extinguishing systems shall be selected having due regard to the fire growth potential of the protected spaces and are to be readily available.

6.5 Fire dampers

6.5.1 Air inlet and outlet openings shall be provided with fail safe automatic closing fire dampers which shall be operable from outside the fuel cell space.

6.5.2 Before actuation of the fire-extinguishing system the fire dampers shall be closed.

■ *Section 7*
Testing and trials

7.1 Testing

7.1.1 The fuel cell modules are to be factory tested in accordance with a recognised National or International Standard acceptable to LR.

7.1.2 The fuel cell power system is to be factory tested in accordance with an approved test schedule.

7.2 Trials

7.2.1 Commissioning tests and trials of the fuel cell power system are to be carried out in accordance with a testing programme which is to be agreed by LR, and all tests are to be carried out in the presence of a Surveyor.

7.2.2 Trials are to include the testing of all alarms and safeguards associated with the fuel cell power installation for all modes of operation as defined in the service profile.

Part 6, Chapter 2
Electrical Engineering

■ *Section 1*
General requirements

1.15 Labels, signs and notices

1.15.5 Electrical equipment that presents an electric arc-flash hazard to personnel is to be clearly marked, *see Pt 6, Ch 2, 8.1 General 8.1.1.*

■ *Section 7*
Switchgear and controlgear assemblies

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. The warning of the presence of electric arc-flash hazards is also to be shown. Section and distribution boards are to be marked with the rated voltage.

Part 7, Chapter 13
On-shore Power Supplies

■ *Section 3*
Electrical ~~Connection~~ connection

3.3 Connection cables, plugs and socket-outlets

3.3.3 Type tests are to be carried out on power connection plugs and socket-outlets and cables, in accordance with IEC 62613-1~~:~~ *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC Systems) – Part 1: General requirements* and Annex A.3 of ~~the~~ IEC/ISO/IEEE 80005-1~~:2012:~~ ~~*Electrical installations in ships – Special features*~~ *Utility connection in port — High voltage shore connection (HVSC) Systems-General requirements*: ~~*High-voltage shore connection systems respectively*~~ *High voltage shore connection systems* or a relevant National Standard, to verify design suitability for the intended application described in the Design Statement. Type test reports are to be submitted that include details of the standards, the tests conducted and their order, and the acceptance criteria. Alternative proposals may be submitted for consideration.

3.3.7 Ship-to-shore connection cables are to be in compliance with IEC 80005-1 *Utility connections in port — Part 1: High voltage shore connection (HVSC) systems — General requirements Annex A.*

3.5 High voltage in the presence of personnel

3.5.1 A formal written detail of isolations and earthing in the form of permit to work is to be completed prior to the vessel arriving at the berth to receive. This is to ensure that the correct shore connection point is ready to receive shore power and the unused shore connection point, if fitted, will not be energized when shore power is connect to the vessel potentially causing an electrical hazard to personnel. A copy of a permit to work form can be found at Annex C of IEC 60092-509 *Operation of electric installations*.

Existing paragraph 3.5.1 has been renumbered 3.5.2.

~~3.5.2~~ 3.5.3 For high voltage:
(a) switchgear and controlgear assemblies;
(b) cable reels, cranes and gantries; and
(c) mounting enclosures for socket-outlets used to connect flexible cables to fixed connections~~;~~,

arrangements are to be made to protect personnel in the event of gases, arc flash or vapours escaping under pressure as the result of arcing due to an internal fault. Where the Defined Operations require personnel to be in the vicinity of such equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex ~~A~~ AA of IEC 62271-200 *High-voltage switchgear and controlgear — Part 100: High-voltage alternating-current circuit-breakers* and qualified for classification IAC (internal arc classification), or equivalent.

■ *Section 4*
Electrical ~~System~~ system

4.3 Protection

4.3.9 For high voltage connections means are to be provided to ensure the circuit breaker cannot be closed when any of the following conditions exist:
(a) one of the earthing switches is closed (shore-side/ship-side);
(b) the safety circuit is not established;
(c) emergency-stop facilities are activated;
(d) ship or shore control, alarm or safety system self-monitoring diagnostics detect an error that would affect safe connection;
(e) the data-communication link between shore and ship is not operational, where applicable;
(f) the permission from the ship is not activated;
(g) the HV supply is not present;
(h) equipotential bonding is not established (via equipotential bond monitoring devices where utilised, or via manual override);
(i) the cabinet door is in the open position; or
(j) cable plugs both shore and ship are not fully inserted into the socket.

4.3.10 Means are to be provided to ensure that the disconnector cannot be closed, or the circuit breaker cannot be racked into service position when any of the following conditions exist:
(a) one of the earthing switches is closed (shore-side/ship-side);
(b) the safety circuit is not established;
(c) the communication link between shore and ship is not operational, where applicable; or
(d) equipotential bonding is not established (via equipotential bond monitoring devices where utilised, or via manual override).

Existing paragraph 4.3.9 has been renumbered 4.3.11.

■ *Section 5*
Control and monitoring

5.3 Emergency ~~Shutdown~~ shutdown

5.3.2 ~~Emergency Shutdown facilities are to be provided that, when activated, will instantaneously:~~ Emergency shutdown facilities are to be provided, in accordance with clause 4.9 of IEC 80005-1 *Utility connections in port — Part 1: High voltage shore connection (HVSC) systems — General requirements*, that:

- ~~isolate the connection from ship electrical power supplies; and~~ When activated, will instantaneously open shore connection circuit-breakers onshore and on-board ship.
- Fail-safe hard-wired circuits (safety circuits) shall be used for emergency shutdown. This does not preclude emergency shutdown activation commands from programmable electronic equipment, for example programmable protection relays.
- The relay contacts of the safety circuit shall be designed in accordance with IEC 60947-5-1 *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices* and for a rated insulation voltage of *Ui* = 300 V, AC 5 A, DC 1 A.
- Minimum current value in the safety circuits shall be 50 mA.
- ~~request isolation of the external electrical power supply connection points.~~
- These facilities are to be automatically activated (*see Pt 7, Ch 13, 5.3 Emergency shutdown 5.3.6*).

5.3.6 To detect and react to the withdrawal of plugs from ~~socketoutlets~~ socket-outlets while power supply connections are live, the ~~Emergency Shutdown~~ emergency shutdown facilities described in *Pt 7, Ch 13, 5.3 Emergency ~~Shutdown~~ shutdown 5.3.2* are to be activated automatically, opening the ship and shore HVSC circuit breakers in a maximum time of 200 ms, before the necessary degree of protection is no longer achieved or power connections are broken by the removal of a plug from a connected socket-outlet, including in-line connections.

5.3.10 Means to manually activate the ~~Emergency Shutdown~~ emergency shutdown facilities described in *Pt 7, Ch 13, 5.3 Emergency ~~Shutdown~~ shutdown 5.3.2* are to be provided ~~at~~:

- at a machinery control station that is attended when connected to an external electrical power supply;
- in close proximity to the connection cubicle; ~~and~~
- at the switchboard where the fixed cables from the shore connection cubicle are received;~~.~~ and
- at active cable management system control locations.

5.3.12 The emergency shutdown facilities are to be activated in the event of:
(a) loss of equipotential bonding, via the equipotential bond monitoring devices (where utilised);
(b) over-tension on the flexible cable (mechanical stress); *see* IEC/IEEE 80005-1 *Utility Connections in Port — High voltage shore connection (HVSC) systems – General requirements*;
(c) the remaining cable length being too short; *see* IEC/IEEE 80005-1 *Utility Connections in Port — High voltage shore connection (HVSC) systems – General requirements*;
(d) loss of any safety circuit;
(e) activation of any manual emergency-stop;
(f) activation of protection relays provided to detect faults on the HV connection cable or connectors; and
(g) disengaging of power plugs from socket-outlets while HV connections are live before the necessary degree of protection is no longer achieved.

5.4 Data communication link

5.4.1 The data communication link between ship and shore arrangements, where applicable, is to be used for communicating the following information:
(a) shore transformer high-temperature alarm;
(b) HV shore supply circuit-breaker protection activation, *see Pt 7, Ch 13, 3.1 General 3.1.3*;
(c) permission to operate HV circuit-breakers for HV ship-to-shore connection;
(d) if ship or shore control, alarm or safety system self-monitoring properties detect an error that would affect safety of connection, *see Pt 7, Ch 13, 4.3 Protection 4.3.9*;
(e) indication of emergency-stop activation, *see Pt 7, Ch 13, 5.3 Emergency shutdown 5.3.11*;
(f) where provided, shore control functions, *see Pt 7, Ch 13, 4.1 Electrical Load Transfer 4.1.4;*
(g) indication of emergency disconnection of the shore supply, *see Pt 7, Ch 13, 5.3 Emergency shutdown 5.3.11*; and
(h) failure of the battery's charging or activation of the back-up system.

The communication protocol for the communication link between ship and shore shall be in accordance with IEC/IEEE 80005-2 *Utility Connections in Port — High and low voltage shore connection systems — Data communication for monitoring and control* or an equivalent standard acceptable to LR.

■ *Section 6*
Testing, trials and surveys

6.1 General

6.1.6 Earthing bonding connections. Where equipotential bonding is not continuously monitored, the following procedures are required:

(a) Physical connection points shall be inspected prior to each connection being made or at a periodicity not exceeding 12 months.

(b) Ship-side bonding connection resistance shall be measured at a periodicity not exceeding six months. Results shall not exceed 1 Ω.

Measurement methods are site-specific and shall be documented, *see Pt 6, Ch 2, 1.12 Documentation required for design review*.

Existing paragraph 6.1.6 has been renumbered 6.1.7.

Part 8, Chapter 2
Ice Operations – Ice Class

■ *Section 4*
Hull requirements for light ice conditions – Ice Classes 1D and 1E

4.3 Shell plating

(Part only shown)

4.3.1 The shell plating thickness within the region shown in *Figure 2.4.1 Extent of application of plating requirements* is not to be less than:

$$\cancel{t = 21{,}75s\sqrt{k(\frac{BL^2}{110000}+1)(1{,}3-\frac{4{,}2}{(\frac{0{,}26}{s}+1{,}8)^2}}+2\text{ mm}}$$

$$t = 21{,}75s\sqrt{k(\frac{BL^2}{110000}+1)(1{,}3-\frac{4{,}2}{(\frac{0{,}26}{s}+1{,}8)^2}}+t_s,\text{ mm}$$

t_s = the increment for abrasion and corrosion is normally 2 mm. If a recognised abrasion resistant coating, shown by experience to be capable of withstanding abrasion by ice, is applied and maintained, this can be reduced to 1 mm. *See* the *Rules for the Manufacture, Testing and Certification of Materials, Ch 15 Corrosion Prevention, 2.13 Ice coatings.*

■ *Section 10*
Hull strengthening requirements for navigation in multi-year ice conditions – Ice Classes PC1, PC2, PC3, PC4, PC5, PC6, PC7 and Icebreaker

10.17 Corrosion/abrasion additions and steel renewal

10.17.2 The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness are listed in *Table 2.10.7 Corrosion/abrasion additions for shell plating*. *See* the *Rules for the Manufacture, Testing and Certification of Materials, Ch 15 Corrosion Prevention, 2.13 Ice coatings*.

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